H. W. Ulmer

SEALING GLASS TO KOVAR

ITS TECHNIQUE AND APPLICATIONS

BULLETIN 145

STUPAKOFF CERAMIC AND MANUFACTURING COMPANY
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Bulletin No. 145

SEALING GLASS TO KOVAR*

A Treatise on the Subject of
Glass to Metal Sealing with **KOVAR**
"The Ideal Alloy for Sealing to Glass"

STUPAKOFF CERAMIC AND MANUFACTURING COMPANY
Products for the World of Electronics
PHONE LATROBE 1400
LATROBE, PENNSYLVANIA
EXPORT DEPARTMENT—13 E. 40th ST., NEW YORK 16, N. Y.
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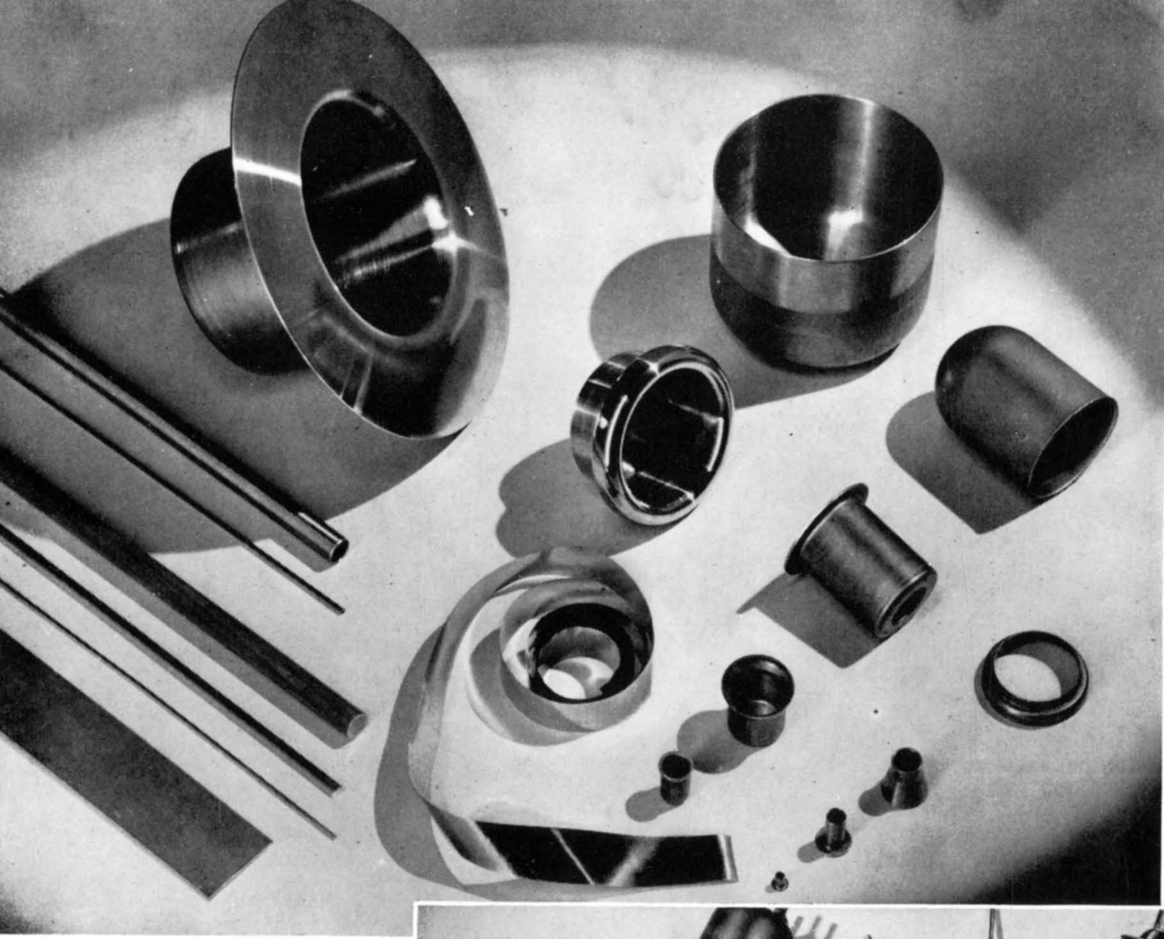

Kovar is available as rod, wire, tubing, sheet, foil or fabricated into cups, eyelets or special shapes.

Illustrations of typical Kovar-Glass Seals.

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GLASS TO KOVAR HERMETIC SEALING

"Hermetically sealed" is a "must" specification for many types of electronic components. While the value of Kovar-Glass seals has been proven for years in electronic tubes, their use as protectors of other vital electronic equipment have been established beyond doubt during the war, especially in the humid and fungus laden reaches of the Pacific.

Equipment can be hermetically sealed to withstand thermal shock and resist humidity and fungus attack, with improved performance and longer life over equipment protected by ordinary methods.

Webster defines hermetic as "perfectly closed and airtight by means of fusion". Therefore, unless there is a fusion of the materials making up a seal, the seal cannot be rightly called hermetic. Many so-called hermetic sealing devices are not fused but depend on cements, gaskets or both for their effectiveness.

It is the purpose of this work to introduce the elements that go to make up a true hermetic seal and to explain sealing techniques that have been developed in the last ten years.

In the quest for a sealing material, glass immediately suggests itself as having desirable characteristics. It is impervious to climatic conditions and fungus attack; is a dense, vitreous material ideal for vacuum tight sealing purposes; offers adequate mechanical strength and is resistant to thermal shock providing it is a glass of low expansivity. This last is very important since there are types of seals available which employ soft glass as the sealing agent and are therefore inferior in thermal shock characteristics and weathering qualities. Glass has excellent electrical qualities which provides high insulation values. In some cases, such as in lamps, photoelectric cells, windows, etc., glass is desirable because of its light transmission characteristics.

Having established hard glass as the ideal sealing agent it is necessary to provide a conducting or metallic material that will readily bond with it without producing structural stresses over an extreme temperature range. Various metals seal to glass but fail to offer all of the characteristics necessary for an ideal glass-sealing material. The ideal characteristics of such a material are:

1. Must readily seal into hard or thermal shock resistant type glass.
2. Must have substantially the same expansivity as the glass from −80°C to the annealing point of the glass.
3. Must produce a permanent vacuum tight seal.
4. Must be readily machined or fabricated to permit the use of small and intricate shapes.
5. Must be of controlled composition to permit duplication of results.
6. Must resist mercury attack.
7. Must be usable without need for feather edge on tubular or intricate shapes.

8. Must be relatively inexpensive, eliminating restraints on sizes and capacity.
9. Must be weldable, solderable, and brazeable to other metals.

Kovar, a cobalt, nickel iron alloy, developed and perfected by Westinghouse Electric Corporation, possesses all of the virtues described above. Specific properties of Kovar are shown in Table I and Graph I shows the expansion curve of Kovar as compared to two hard glasses. Used commercially since 1934, Kovar is, at this writing, the only alloy available which was specifically developed for sealing to hard glass.

The recommendations for producing hermetic seals which follow are based on the experience of many who have worked with the problem. These recommendations should serve as a guide and are not to be construed as hard and fast rules, since new processes are being continually developed which might offer advantages over present methods.

Stupakoff has set up a research staff to investigate properties of the metal under all conditions of useage and will make this information available at all times.

It is the aim of this bulletin to furnish basic fundamentals which, if followed, will produce hermetic seals possessing required electrical and mechanical properties.

Work, both in sealing techniques and in the application of Kovar-glass seals has been done by Stupakoff Ceramic and Manufacturing Company, distributors and fabricators of Kovar.

HOW KOVAR IS MADE

Kovar is a cobalt, nickel iron alloy which must be manufactured under laboratory conditions to assure success in its many applications. In order to meet the high standards required so that the characteristics of Kovar are always the same, every phase of its manufacture is handled by engineers, trained in the ability to handle stringent and intricate procedure.

The first and perhaps most important step in the procedure is to select or treat the raw materials so that they will have the necessary purity. The materials are then charged into electric induction furnaces where the melting is accurately controlled. A high proportion of each ingot made is cropped and machined to remove any material or condition which would result in imperfection in the finished product.

These purified billets are then reduced to sheet, rod, wire or tubing, during which many intermediate hydrogen anneals are necessary. At several steps during processing, qualitative control tests are made on each heat and final expansion measurements are made to insure that Kovar meets specified limits. In addition, actual glass seal tests are made in which the seals must withstand subjection to a temperature of 80°C. These exhaustive tests are made to insure the successful operation of many devices which are dependent upon hermetic seals.

TABLE 1

SPECIFIC PROPERTIES OF KOVAR "A"	
Composition	29% Nickel, 17% Cobalt, 0.3% Manganese, balance Iron.
Melting Point	1450°C. (Approximate).
Density	.302 lbs. per Cubic Inch.
Hardness—Annealed	760°C.—140–160 B.H.N.
Hardness—Unannealed	200–250 B.H.N. depending on degree of cold work.
Specific Electrical Resistance	49 microhm cm.—294 ohms per cir. mil. foot.
Thermal Conductivity	0.0395 Calories/cm/sec/°C.(Approximate as measured at room temperature).
Curie Point	435°C. Approximate.

PHYSICAL PROPERTIES OF .030 THICK SHEET TESTED PARALLEL TO THE DIRECTION OF ROLLING	
Yield Point	50,500 P.S.I.
Proportional Limit	32,300 P.S.I.
Tensile Strength	89,700 P.S.I.
Modulus of Elasticity	20 x 10^6 P.S.I.

THERMAL EXPANSION—After annealing in hydrogen for one hour at 900°C. and for 15 minutes at 1100°C. The average coefficient of thermal expansion of Kovar "A" falls within the following limits:	
30°—200°C.	4.33 to 5.30 x 10^{-6} per °C.
30°—300°C.	4.41 to 5.17 x 10^{-6} per °C.
30°—400°C.	4.54 to 5.08
30°—450°C.	5.03 to 5.37
30°—500°C.	5.71 to 6.21

MAGNETIC PERMEABILITY

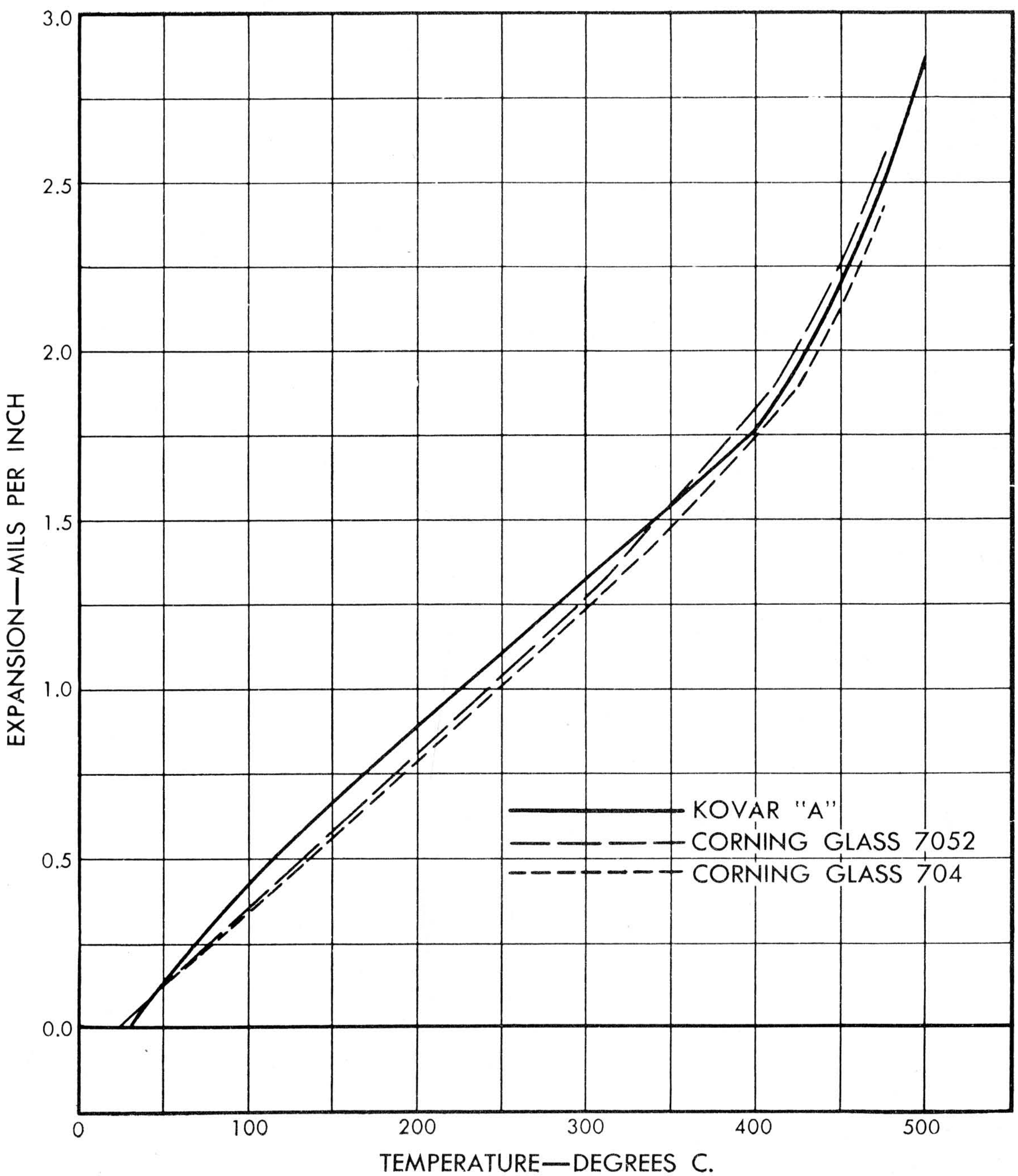
Magnetic Permeability	Flux Density (Gausses)
1000	500
2000	2,000
3700	7,000 (max. value)
2280	12,000
213	17,000

MAGNETIC LOSSES (Watts per Lb.)

Thickness	10 Kilogausses 60 Cycles Sec.	10 Kilogausses 840 Cycles Sec.	2 Kilogausses 5000 Cycles Sec.	2 Kilogausses 10,000 Cycles Sec.
.010	1.05	23.4	16.6	41.0
.030	1.51	....	....	....
.050	2.77	....	....	....

Tensile strength of KOVAR Glass Seals is 600 lbs. sq. inch.
All of the above are typical values.

GRAPH I



A comparison of the thermal expansion of Kovar "A" with two commercial glasses

TECHNIQUES IN GLASS TO METAL SEALING

Absolute control over every operation involved in producing a hermetic seal is required if the seal is to meet the required standards necessary to positive sealing.

POLISHING—The Kovar sealing surface should be free from marks or scratches which run from the sealing surface to the outside. Radial marks are not considered objectionable, in fact, some engineers prefer a rough surface feeling that it produces a stronger seal. When an edge seal is made, the sealing edge should be well rounded. An exact radius is not required but sharp corners must be eliminated. The surface finish required prior to sealing may be attained by the following described operations. Burrs may be removed from cut parts by tumbling or other mechanical means. Sharp edges may be eliminated by radiusing with forming tools. Draw marks and deep scratches may be removed by using aloxite cloth or sticks of #120 grit at a surface speed of 400 feet per minute. It is recommended that for high or finished polishing, aloxite cloth of #240 to #320 grit be used. Centerless ground stock requires no polishing.

MACHINING—Kovar machines readily at slow speeds with high speed cutting tools with a satisfactory lubricant such as lard oil. In lathe turning, Kovar acts similar to stainless steel and a suitable tool has the following specifications:

Back Rake	8—12°
Side Rake	6— 8°
End Relief	3— 6°

DEEP DRAWING—Kovar deep draws readily and in this respect is slightly better than mild steel. The recommended rule for deep drawing Kovar is as follows:

	Maximum Reduction
First Draw	40%
First Redraw	25% (30% after reanneal)
Second and Subsequent Redraws	20% (25% after reanneal)

This means that with a 1.0″ diameter blank, the cup diameter after the first drawing operation should not be less than 0.6″.

Kovar sheet is supplied in a fully annealed condition ready for deep drawing unless otherwise specified. Subsequent annealing is required only when the length of the cup equals or exceeds the diameter. Using the tabulated rule for drawing, an anneal should be made after the first re-draw, and when drawing long cups, an anneal should follow the third redraw, fifth redraw, etc.

Kovar parts are stress relieved when subjected to a temperature of 700°C to 1000°C for a one hour period. It is preferable that this annealing be done in a hydrogen atmosphere, but if this is not readily available, a furnace with a neutral atmosphere may be used, provided the usual hydrogen anneal just prior to sealing is employed.

Only those drawing compounds should be used which can be removed completely by trichlorethylene or equivalent.

Spinning of Kovar is not recommended since there is danger of fracturing the metal which may result in vacuum leaks. For experimental models, spinning of Kovar parts can be done if extreme care is exercised, including frequent intermediate anneals.

CLEANING—Kovar parts must be absolutely clean to facilitate proper sealing. Cleaning can be accomplished satisfactorily by vapor degreasing and it is imperative that the fluid used be free of residual greases. An acetone wash after degreasing insures cleanliness. It is recommended that degreasing equipment be used exclusively for cleaning Kovar to eliminate the possibility of contamination.

DEGASSING AND ANNEALING—When the Kovar is not free of occluded gases or carbonaceous matter, gas bubbles will appear in the finished seal along the metal interface. Such bubbles will reduce the mechanical strength, impair gas tightness and reduce dielectric values. Therefore, the Kovar must be furnace degassed in a hydrogen atmosphere made moist by bubbling hydrogen through water.

The above also serves as a strain relieving anneal, a further requisite for a good seal.

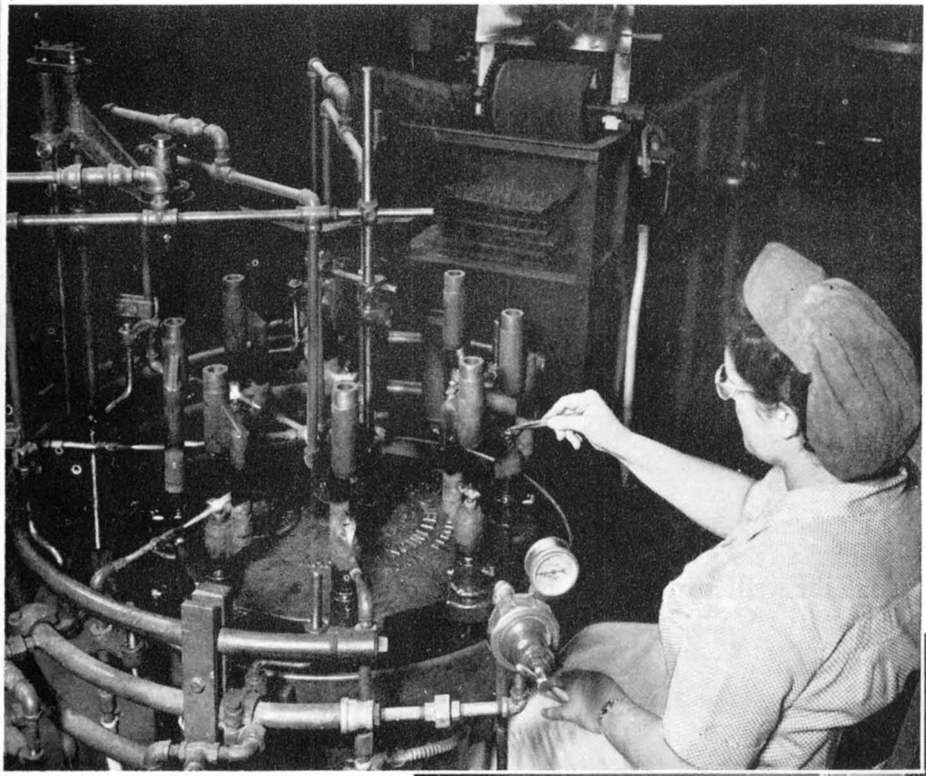
Cleaned Kovar parts are placed in a heat-resisting alloy basket or boat with the precaution to avoid containers of high carbon content. The loaded containers are charged into a furnace equipped with a cooling chamber. The furnace may be operated with satisfactory results under any of the following schedules.

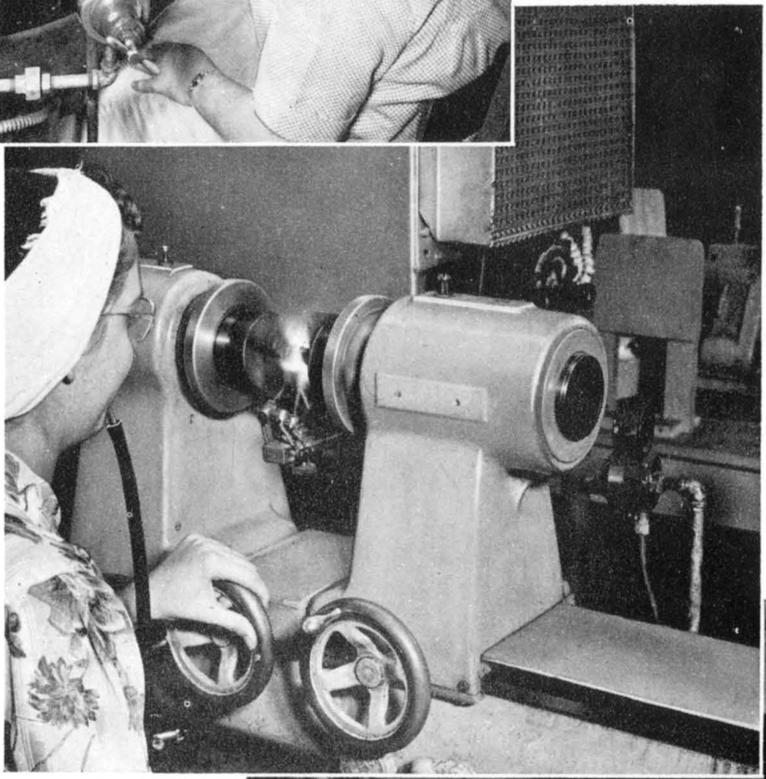
1. 800° to 900°C—2 hrs.—then to a cooling zone where cooled to under 300°C before removal.
2. 900° to 1000°C—30 min.—then to a cooling zone where cooled to under 300°C before removal.
3. 1100°C—10 to 15 min.—then to a cooling zone where cooled to under 300°C before removal.

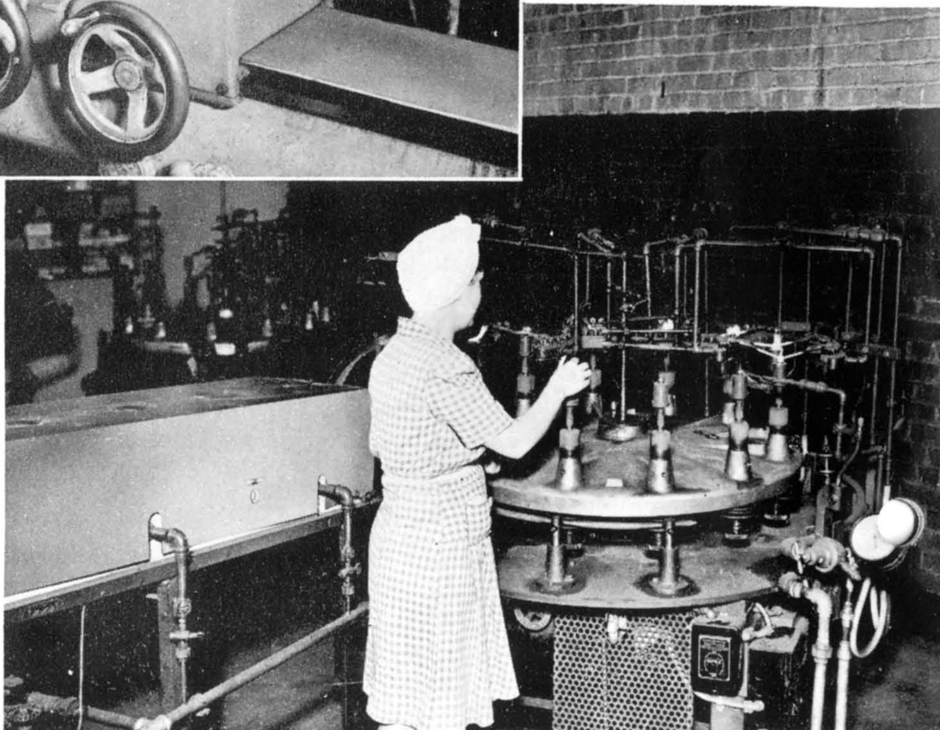
It is recommended that degassed Kovar parts be protected from grease laden atmospheres prior to sealing and that parts be sealed within a few hours after degassing.

Extreme caution should be exercised in handling the degassed Kovar in making the assembly. Specifically, parts should not be touched by bare hands as grease from the hands may cause bubbles. Mishandling of the parts after cleaning and degassing defeats the purpose of these operations.

FORMATION OF OXIDE—It is necessary to form a film of oxide on the Kovar part either during the actual sealing operation or prior to the sealing operation. Preoxidation of the Kovar is preferable in most cases since it results in a more evenly formed oxide film. Oxidation of the Kovar parts can be accomplished by rapidly heating the metal to over 650°C in a slightly oxidizing atmosphere. Excessive oxidation is not likely to occur since the







flame gases provide some protection. The Kovar parts should not be heated in the reducing portion of the flame. The degree of desired oxidation is difficult to determine objectively. Uniformity may be accomplished by batch oxidation of parts in a furnace. It is significant that heavily oxidized Kovar produces seals which are porous but mechanically strong, whereas inadequately oxidized seals are more gas tight at the sacrifice of mechanical strength. Under-oxidized seals present a light, metallic appearance while over-oxidized seals are dark, almost black in appearance. Correct oxidation results in a seal having a mouse-gray or brownish appearance depending on the glass used. It must be noted that Kovar oxide is more readily soluble in Corning #705-2 glass than in Corning 704 glass. For that reason, seals made with 705-2 glass are lighter in color than seals made with 704 for the same degree of oxidation.

Excessive oxide may be dissolved by either prolonged heating or increased sealing temperature. Caution must be exercised in this bleaching action since extremes in either procedure may result in de-vitrification of the glass.

GLASS PREPARATION—Glass tubing or cane may be cut to required lengths with a wet abrasive wheel. Satisfactory cutting may be done with a bonded abrasive cutting wheel of #180 to #240 grit at a surface speed of 8000 feet per minute.

Cutting should not be forced since it causes scoring of the glass which results in abrasive inclusions. This will cause cloudy sealing.

The diamond cutting wheel #250 to #400 grit is most satisfactory from a standpoint of precision cutting.

To cleanse glass after cutting, wash the glass in water, rinse in 10% hydrochloric acid and boil in distilled water. Cleansed glass should be protected from dust until utilized in the sealing operation. The design of the seal should be the determining factor in the type of glass selected. Glasses of high coefficient of expansion when sealed to the inside of tubing or a cup may develop a strain frequently resulting in fracture.

SEALING—Fundamentally the seal between Kovar and glass is a chemical bond formed through a heating process in which the oxide of Kovar is dissolved into the glass. The sealing technique is basically that of wetting the oxide with glass in the plastic state. The glass is brought to a viscosity of 10^1 poises at about 850°C and in this condition is applied to the hot (over 650°C) oxidized Kovar. The design and size of the seal determines whether the heating shall be localized to the area of the seal or spread over a greater area to prevent fracturing. Slight pressure of the glass on the metal initiates the sealing action and some mechanical working of the glass may be employed. Pre-beading of the glass onto the metal is helpful in some cases. The glass contour may be controlled by flame impingement, flame intensity and by mechanical means but care must be exercised to avoid entrapped bubbles or air pockets. As previously stated, a seal properly made with #704 Corning glass should have a brownish-gray appearance while a seal employing 705-2 Corning glass will have a silvery or mouse-gray appearance.

Feathering of the glass along the surface of the metal should be avoided to insure maximum mechanical strength.

GRADED SEALS—When it is desired to make a seal between Kovar and a glass of non-matching expansivity, a graded seal is required. For example when Pyrex glass is involved, the order is Kovar and the following Corning glasses: 705 AJ or 705 BA, 702 P, Uranium and Pyrex. The size and design of the seal may permit the elimination of one or more of the intermediate glasses. Very fine wires of Kovar have been sealed directly to Pyrex and some heavier seals have been made between Kovar and 702 P.

SEALING FUELS—In common practice natural gas, artificial gas or hydrogen is used in various proportions with air, oxygen and air, or oxygen. The pressures used are determined by burner types, apertures and B.T.U. content as well as the specific application.

ELECTRONIC SEALING—High frequency current ranging from 40,000 to 60,000 cycles per second, generated by spark or vacuum tube generators may be utilized in Kovar-glass sealing. It is imperative that glass and metal parts be in intimate contact since the working temperature of the glass is attained by conduction from the Kovar. In certain applications the high frequency sealing technique may be employed to advantage because heating is localized and glass deformity takes place only at the point of metal contact.

STRESS RELIEF IN KOVAR-GLASS SEALING—When the recommended glasses having correct expansivity are used, seals with Kovar can be obtained within permissible stress limits at room temperature. Flame annealing of the seal is frequently used for stress relief. A carbon deposit from a yellow flame prevents an undesirable cooling rate. A general batch annealing program suitable to proper annealing of most seals of varying shape or size is as follows:

1. Room to annealing temperature of the glass—30 minutes.
2. Hold at annealing temperature of glass—20 minutes.
3. Annealing temperature to strain point 1°C per minute.
4. Strain point to room temperature 7°C to 10°C per minute.

Continuous annealing programs may be set up for production items, the program being designed for strain relief of a specific seal. The program is governed by the nature of the glass and the dimensions of the seal. Where seals are to be subjected to thermal shock it is often desirable to develop residual stress in the glass by accelerated cooling. This is frequently accomplished by an air blast.

CLEANING OXIDIZED KOVAR—The oxide on Kovar resulting from the sealing operation must be removed prior to soldering, welding or brazing. This cleaning may be done by pickling either electrolytically or by immersion, but the former is preferred because of the speed of the operation and the small loss of metal.

An electrolytic pickling bath consists of 5 to 10% sulphuric acid in water to which has been added an inhibitor, such as 1% Quinoline or 1% Rodine #110. The percentage of the inhibitors is by weight of dilute acid. Another satisfactory electrolytic pickling bath is a common salt solution containing 10 to 15% Hydrochloric Acid. With either of the above the Kovar part to be cleaned is used as one electrode, the other being carbon or another piece of Kovar. An alternating current of 10 to 12 volts at a current density of approximately 10 amperes is used for each square inch of Kovar surface. The pickling time should be determined experimentally for particular pieces. In some cases it may be necessary to remove the loose oxide with a cloth or brush.

Normal pickling may also be employed for oxide removal, using a solution of 10% Hydrochloric Acid and 10% Nitric Acid by weight, heated to approximately 160°F. Two to five minutes immersion, depending on the degree of oxidation, is usually sufficient time to loosen the oxide scale which must be removed by wiping. After pickling the metal surface is usually light-gray but may have a bright appearance. Pickling is accomplished by the evolution of a small amount of gas. Pickling should be followed by dipping in a lime solution to neutralize the acid adhering to the Kovar. Another effective immersion pickling bath is as follows:

50% Hydrochloric Acid Solution (Tech. grade)	2,000 CC
50% Nitric Acid Solution (Tech. grade)	100 CC
Spent Solution (Inhibitor)	1,500 CC
Working Temperature	160°F

Oxide on the exposed metal portions of seals may be removed by the reducing action of a hydrogen atmosphere but this method should be used with extreme caution for vacuum seals, because of the danger of removing oxide where the glass joins the metal. Satisfactory results have been obtained by raising the seals to 600°C in a hydrogen atmosphere for 30 minutes and then gradually cooling in hydrogen to at least 200°C before removal. The time in the deoxidizing zone depends upon the degree of oxidation. Close control of furnace temperature is essential and the reducing procedure must be followed by the regular glass annealing program to remove strains in the glass, or may be done on a program which will affect annealing during cooling. In any case the anneal must be in hydrogen or a non-oxidizing atmosphere.

ELECTRO-PLATING—Kovar may be plated with various metals. Tin plating is generally used in soldering. An alkaline electro-tinning process (Sodium stannate-acetate) provides ease of control and a smooth white plate. Adherent deposits of .0003" give full, uniform corrosive protection. With a good deposit of average thickness there are no thin spots to wear quickly and allow the base metal to corrode. Both dip or barrel plating facilities provide excellent results.

During the pickling operation, metal salts are formed which cannot be completely removed by ordinary water rinsing. By the use of a 5% sodium cyanide dip it is possible to remove these, thus providing a better surface for plating.

TIN FLOWING—Electro-tin plated Kovar parts become increasingly difficult to solder after exposure to air. This difficulty can be overcome and a better tin coverage obtained by flowing the plated tin by immersion in hot fatty acids such as Crisco or Corn Oil. Acid value should be less than 1.

Parts should be immersed in flowing oil and held at a temperature of 450°F until the part shows a bright tin. The flowing oil can be removed by a degreasing operation.

SOLDERING—Soft soldering of Kovar is rarely used on high vacuum or gas filled devices such as electronic tubes because the operating temperatures are usually sufficiently high to cause objectionable vaporization of the solder. In non-high vacuum apparatus soft soldering, however, is a preferred method of attaching Kovar-glass assemblies to other metals.

When soldering Kovar-glass seals, it must be understood that while Kovar and glass have a closely matching expansion, the heat conductivity of these two materials is dissimilar. The preferred soldering method, therefore, is one which employs a gradual heating and cooling process to eliminate localized and sudden heat changes.

A soldering iron may be employed if carefully used. Both soldering surfaces should be pre-tinned to keep the necessary applied heat to a minimum.

Hot tin dipping has been found satisfactory and in this method pre-heating of the assemblies is recommended.

While there are instances where it has been successfully used, high frequency soldering is not generally recommended due to the heat shock involved.

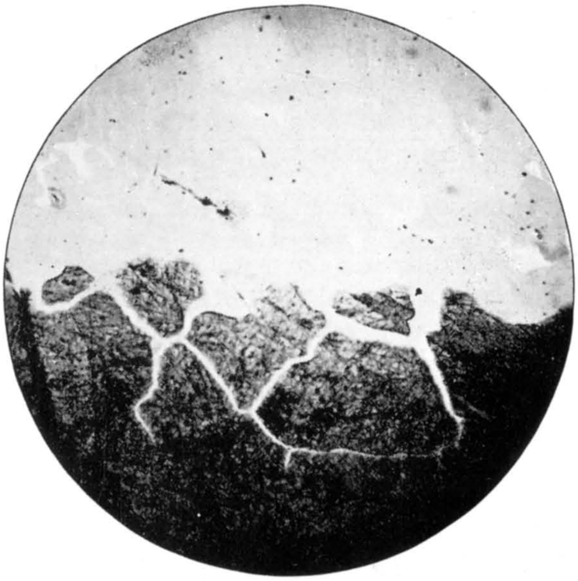
Tin lead solders of 50-50, 60-40, or eutectic compositions have been found very satisfactory.

Because of the increased difficulty of soldering parts after several days exposure, a resin alcohol dip which has both a protective and fluxing action may be used. Zinc chloride fluxes should be avoided since the salt is highly conductive and difficult to remove from the glass.

WELDING—It is essential that the surface of the Kovar be absolutely clean. Excellent joints are made on Kovar welded to soft steel by atomic hydrogen welding and also by electric arc and resistance welding. For arc welding, the use of flux-cooled electrodes of either 18% chrome and 8% nickel or 25% chrome and 12% nickel are recommended.

Welding of Kovar is usually confined to structures before sealing. However, a special strain relief eyelet (Patent No. 2318435) has been developed which permits resistance welding after the seal has been made. It is also possible to weld Kovar-glass assemblies by water cooling the glass and the metal adjacent to the glass, but this involves a rather careful technique.

BRAZING—The preferred method of brazing is one which uses pure copper in a hydrogen atmosphere at 1100°C, with the brazing time never more than 15 minutes. If the nature of the structure is such that copper brazing cannot be used, pure silver and pure gold are satisfactory.



Kovar specimen showing intergranular penetration resulting from brazing with a silver alloy. Mag. 100x.

The use of brazing alloys requires close observation and some necessary precautions.

Brazing results in one of three things; either wetting, alloying or intergranular penetration. Wetting is merely an adherence of the solder to the surface of the Kovar which results in a relatively weak joint. Alloying, which with a recommended silver solder occurs above 850°C, is the formation of an actual alloy between the solder and the Kovar which penetrates the Kovar for a reasonable depth. Intergranular penetration, which is accelerated when the Kovar part is under tensional stress, is a penetration of the solder between the grains of the Kovar and can eventually result in a crack through the Kovar, particularly if the Kovar part is repeatedly heated and cooled. The phenomenon of intergranular penetration is common to alloys other than Kovar.

Intergranular penetration can be minimized by brazing with solders which have a flow point above 850°C, as the Kovar will be annealed during the brazing operation and the stresses relieved.

Should a braze be made with a solder which causes intergranular penetration of the Kovar, and should the Kovar part then be used at a low temperature and not heated and reheated, probably no harm will result.

Where it is desirable to use a solder at a flow temperature below 850°C, intergranular penetration can be retarded by first copper plating the Kovar part at the area which is to be brazed. It is desirable to accomplish the brazing in as short a period as possible, preferably less than one minute and in a reducing atmosphere.

When the brazed parts are to be used in connection with a heated high vacuum, precautions should be taken to avoid the use of solders which contain cadmium, zinc, lead and other metals which have high vapor pressure. Fluxes should also be avoided. The effect of such solders and fluxes may be any of the following:

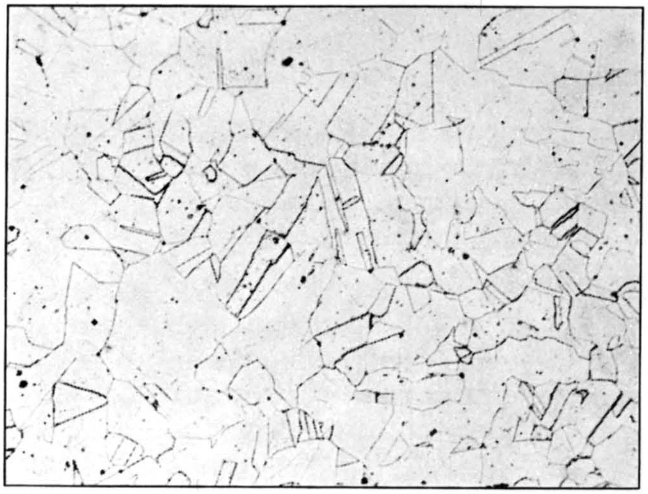
1. Distribution of the high vapor constituent into some other portion of the device where it may be objectionable.
2. A leaky joint due to loss of one of the constituents of the brazing alloy.
3. Corrosion, due to incomplete removal of fluxes.

Flame brazing should be avoided because it results in non-uniform heating of the parts. Best results will be obtained if the parts are brazed in a reducing atmosphere, preferably hydrogen. The brazing should be done in a brazing bottle or a similar container where the brazing can be accomplished by quickly and uniformly heating the section to be brazed.

Prior operations such as welding, riveting, forming, etc., cause stresses which must be removed by annealing before brazing.

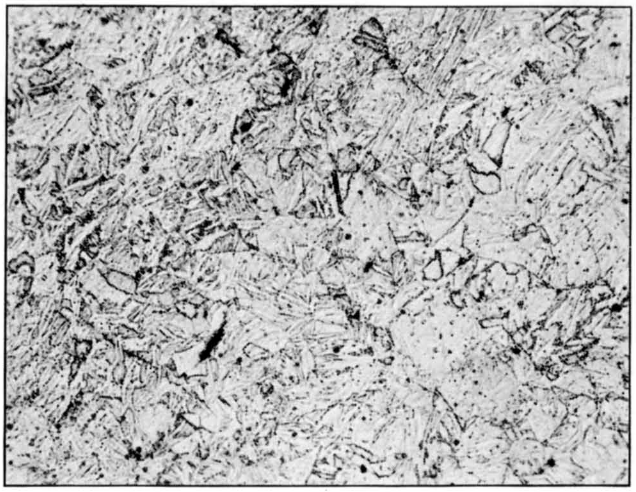
Satisfactory brazing is regularly performed with pure silver, pure gold and pure copper. Alloys of these three metals are also satisfactory provided the previously stated precautions are carefully heeded. It is recommended that the use of solders having a wide melting range be avoided as experience to date indicates that such solders accelerate intergranular growth. For copper to copper brazing or for brazing to copper plated surfaces, solders such as 15% silver, 80% copper and 5% phosphorus (flow point 704 to 750°C) give satisfactory results. The application will determine whether or not the phosphorus solder can be tolerated.

PHASE TRANSFORMATION OF KOVAR—Kovar exhibits phase transformation common to other alloys, the normal structure being the gamma phase with reversible thermal expansion characteristics. The composition of Kovar is such that the gamma to alpha transformation occurs below minus 80°C, a temperature not likely to be attained in service. Cold working, such as rolling and drawing, will cause a partial transformation which can be normalized by annealing.



Mag. 100x

Normal "Kovar"—after treatment in dry ice. Acetone, acetic, nitric etchant. Sample immersed for 30 seconds.



Mag. 100x.

Transformed "Kovar"—after treatment in dry ice. Same etchant as for Fig. 1.

KOVAR STANDARD STOCK SIZES—SHEET, WIRE, ROD and TUBING

KOVAR WIRE (Spooled—Cold Drawn Finish)

Catalog Number	Diameter (Inches)	Approx. Feet per Lb.
920003	.0025	57,000
920005	.005	14,300
920010	.010	3,500
920015	.015	1,500
920020	.020	900
920025	.025	580
920030	.030	400
920035	.035	300
920040	.040	225
920045	.045	175
920050	.050	145
920060	.060	100 (coiled)
920080	.080	55 (coiled)

KOVAR ROD (Straight Lengths—Cold Drawn Finish)

Catalog Number	Diameter (Inches)	Approx. Lbs. per Foot
930060	.060	.010
930080	.080	.018
930100	.100	.028
930125	.125	.045
930156	.156	.060
930188	.1875	.100
930250	.250	.178
930500	.500	.710
930750	.750	1.60
931000	1.000	2.84

Kovar wire is supplied on special order in short, straight lengths to customer's specifications.

KOVAR ROD—STRAIGHT LENGTHS Centerless Ground Finish

Catalog Number	Diameter (Inches)	Approx. Lbs. per Foot
932050	.050	.007
932060	.060	.010
932080	.080	.018
932100	.100	.028
932125	.125	.045

Other sizes can be furnished.

KOVAR TUBING

Catalog Number	Outside Diameter, Inches	Wall Thick., Inches	Approx. Lbs. per Linear Foot
90075010	.075	.010	.0086
90125010	.125	.010	.013
90250010	.250	.010	.028
90250018	.250	.018	.051
90375032	.375	.032	.138

KOVAR SHEET—COILED FORM

Catalog Number	Thickness (Inches)	Width (Inches)	Approx. Lbs. per Sq. Foot
910010	.010	5-3/4	.435
910015	.015	6-1/2	.652
910020	.020	6-1/2	.870

Intermediate widths slit to order.

KOVAR SHEET—FLAT STOCK

Catalog Number	Thickness, Inches	Width, Inches	Length, Inches	Approx. Lbs. per Sq. Foot
910030	.030	13	72	1.305
910050	.050	13	72	2.18
910100	.100	13	72	4.35

FLAT BOTTOM CUPS

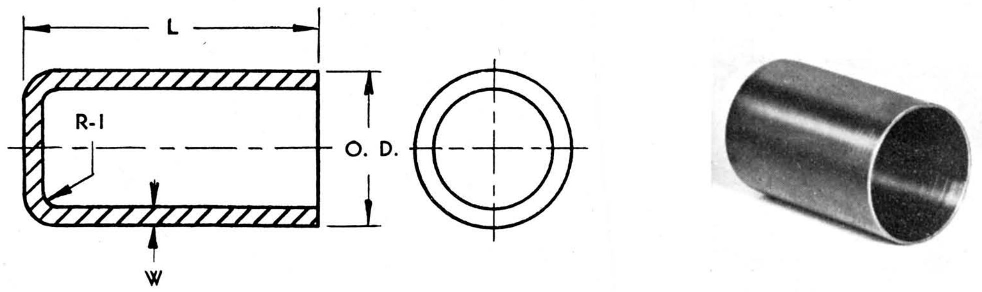


Figure 1

ALL DIMENSIONS IN INCHES

Catalog No.	OD	L	W	R1
940001	.360	9/16	.030	1/32
940002	.375	5/16	.030	1/32
940003	.375	1/2	.030	1/32
940004	.438	7/8"	.030	1/32
940005	.492	1-3/8	.030	.094
940006	.500	5/8	.020	1/32
940007	.500	1/2	.020	1/32
940008	.540	1-5/16	.020	1/32
940009	.604	9/16	.020	1/32
940010	.620	1-1/4	.030	1/8
940011	.625	2-5/8	.030	1/32
*940012	.644	.220	.020	.010
940013	.650	1-1/4	.030	1/16
940014	.650	1-3/8	.030	.094
940015	.675	1-1/4	.030	5/64
940016	.875	21/32	.020	1/8
940017	.900	7/8	.030	1/32
940018	.925	13/16"	.030	1/8
940019	.927	11/16	.030	1/32
940020	1.00	1-3/4	.030	3/32
940021	1.106	2-3/8	.100	1/8
940022	1.125	1-3/4	.030	1/32
940023	1.181	1-3/8	.050	1/8
940024	1.250	3/4	.030	.079
940025	1.250	15/16	.030	1/16
940026	1.250	1-3/8	.030	.079
940027	1.375	1-3/4	.030	9/64
940028	1.375	1-1/8	.030	1/16
940029	1.375	2-1/4	.100	1/8
940030	1.500	1-5/8	.030	1/8
940031	1.612	1-1/2	.030	5/16
940032	1.612	3/4	.050	1/8
940033	1.750	1-3/4	.100	3/8
940034	1.938	7/8	.030	1/8
940035	2.160	1-5/8	.030	1/16
940036	2.401	1-3/4	.100	3/16
940037	2.245	7/8	.030	5/32
940038	2.245	1"	.050	3/8
940039	2.245	2-1/2	.050	3/8
940040	2.250	1-1/8	.100	3/8
940041	2.795	2-1/4	.100	3/16
940042	3.100	3/4	.030	1/8
940043	3.100	1"	.100	3/16
940044	3.100	2-1/8	.100	3/16
940045	4.125	7/8	.100	3/16
940046	4.49	2-3/4	1.00	1/4
940047	4.49	3"	.158	7/16
940048	5.397	3-1/4	.100	3/8
940049	5.51	1-3/4	.100	1/4
940050	5.51	3"	.100	1/4

*Has 4" radius corresponding to R dimension—Figure 3.

FLANGED FLAT BOTTOM CUPS

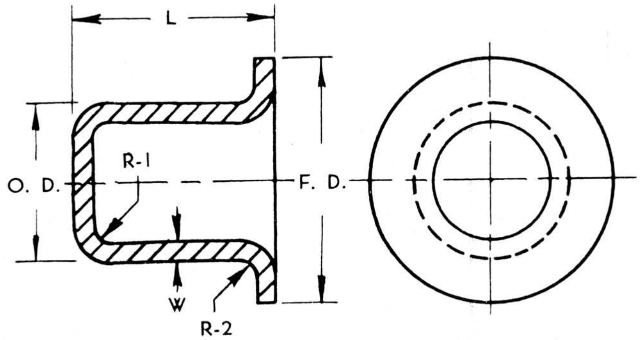
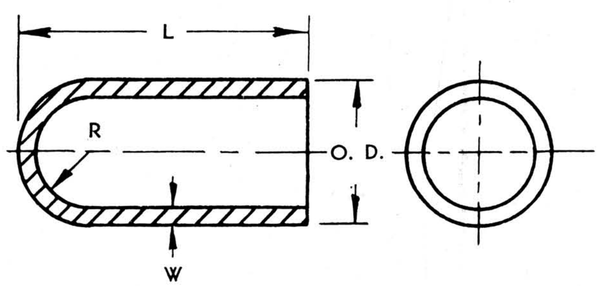


Figure 2
ALL DIMENSIONS IN INCHES

Catalog No.	OD	L	W	FD	R1	R2
941001	.377	25/32	.020	.672	1/32	1/32
941002	.563	.375	.030	1.063	.062	.120
941003	.625	9/16	.030	1.125	1/32	1/32
941004	.875	3/4	.020	1-3/16	1/32	1/32
941005	1.125	1-1/2	.030	1.500	1/32	1/32
941006	1.500	1.125	.030	1.875	1/8	1/32
941007	2.76* 2.81*	1-3/64	.030	3.375	5/64	5/64

*Tapered

ROUND BOTTOM CUPS



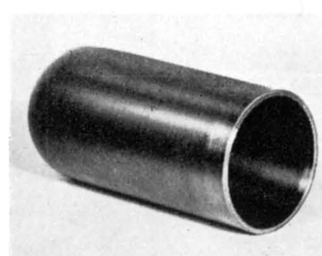
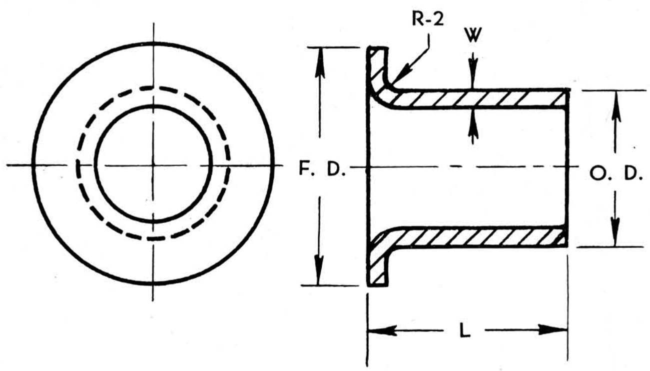


Figure 3
ALL DIMENSIONS IN INCHES

Catalog No.	OD	L	W	R1	R
942001	1.260	2-3/4	.050	...	0.580
942002	1.612	2-1/4	.050	...	0.756
942003	1.969	3-1/4	.050	...	0.934
942004	2.599	2-5/8	.050	...	4.92
942005	3.100	1-3/8	.050	...	4.500
942006	3.100	2-3/4	.050	1/4	4.500
942007	4.000	1-1/2	.050	3/8	4.500

FLANGED EYELETS



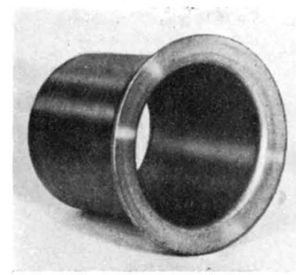


Figure 4

ALL DIMENSIONS IN INCHES

Catalog No.	OD	L	W	FD	R2
943001	.115* to .135	.150	.010	.220	.015
943002	.120	.195	.010	.212	....
943003	.171	.347	.012	.302	....
943004	.195	.150	.015	.280	.015
943005	.205	.135	.010	.340	.015
943006	.205	.395	.012	.340	....
943007	.250	.125	.020	.375	.020
943008	.250	17/32	.020	.438	....
943009	.250	15/32	.020	.375	....
943010	.281	.187	.020	.375	.020
943011	.281	3/16	.020	.500	....
943012	.490	.457	.020	.875	1/32
943013	.500	1″	.020	.844	....
943014	.125* to .135	.100	.010	.200	1/64
943015	.150	.150	.010	.220	1/64
943016	.140	.195	.010	.235	.010
943017	1.030	3/32	.015	1-1/4	1/32
943018	.165	.220	.010	.290	.010

*Tapered

KOVAR "A"
COMMERCIAL SPECIFICATIONS

1. **NORMAL COMPOSITION:** Kovar shall conform to the following requirements as to chemical composition, but no material shall be rejected on chemical composition if it meets the requirements for thermal expansion and temperature of transformation:

Nickel	28.7—29.2 per cent
Cobalt	17.3—17.8 per cent
Iron	52.9—53.4 per cent
Carbon, Max.	0.06 per cent
Manganese, Max.	0.50 per cent
Silicon, Max.	0.20 per cent

2. **TOLERANCES—SHEET:**

a. **Width Limits:** Plus/minus .005" on material slit to size and plus/minus 1/32" for .030" and heavier sheared to size (Std. sheet plus/minus 1/8" wide).

b. **Thickness Limits:**

ALL DIMENSIONS IN INCHES

Thickness	Tolerances	Width	Thick-ness	Tolerance	Width
Under .006	plus/minus .0005	6 & less	.029-.034	plus/minus .0015	Up to 3
.006-.009	plus/minus .00075	6 & less		plus/minus .002	3 to 6
.010-.019	plus/minus .001	6 & less	.035-.049	plus/minus .002	Up to 3
.020-.025	plus/minus .001	Up to 3		plus/minus .0025	3 to 6
.026-.028	plus/minus .0015	3-6	0.50-.160	plus/minus .002	Up to 3
	plus/minus .001	Up to 1		plus/minus .003	3 to 6
	plus/minus .0015	1-6			

c. **Burr on edge limits:** .001" max. for strip of 20 mil thickness and less.

d. **Temper:** Anneal so as to develop deep drawing qualities and the process annealing temperatures should not exceed 1000°C. Maximum B-82 Rockwell.

e. **Finish and Surface:** Bright, clean and free from scale, seams, folds, blisters, and grooves.

f. Above are commercial tolerances. Special tolerances will be considered but with prices in advance of list.

3. **TOLERANCES—WIRE AND ROD:**

a. **Diameter Limits:**

ALL DIMENSIONS IN INCHES

Diameter	Limits	Diameter	Limits
Up to .020	plus/minus .00025	.060 & .080	plus/minus .001
Above .020-.030	plus/minus .0003	1/8 & 5/32	plus/minus .0015
Above .030-.040	plus/minus .0004	3/16	plus/minus .002
Above .040-.060	plus/minus .0005	1/4	plus/minus .005
Above .060-.080	plus/minus .0006	1/2	plus/minus .010
Above .080-1/8	plus/minus .00075	1-0	plus/minus .020

b. **Temper:** Wire—Dead soft anneal.
Rod—Rockwell Hardness B82 Max.

c. Above are commercial tolerances. Centerless ground rod is furnished in any standard diameter to ± .0005″.

4. TOLERANCES TUBING:

Diameter and Wall—(Applicable to only two dimensions, as O.D. and Wall, O.D. and I.D., etc.)

Standard Tolerances are:

O.D. Size	O.D.	I.D.	Wall
Up to, but not including, 3/16″ O.D.	Plus .003″ Minus .000″	Plus .000″ Minus .003″ (See Note 1)	Plus-Minus 10% (See Note 1)
3/16″ up to, but not including, 1/2″ O.D.	Plus .004″ Minus .000″	Plus .000″ Minus .004″	Plus-Minus 10% (See Note 1)
1/2″ up to, but not including, 1-1/2″ O.D.	Plus .005″ Minus .000″	Plus .000″ Minus .005″ (See Note 1)	Plus-Minus 10% (See Note 1)

NOTE 1—Above tolerances apply whenever I.D. is 50% or more of O.D. When under 50% (in cases where tubes can be made), double the I.D. allowance above.

5. FINISH AND SURFACE:

Bright, clean and free from scale, kinks, ripples, seams, slivers and cracks.

6. EXPANSION:

After annealing in hydrogen 1 hour at 900°C. followed by 15 minutes at 1100°C., the average coefficient of thermal expansion in inches per inch per degree C. as determined from the cooling curves shall be—

30° to 200°C. . . . . 4.33 to 5.30 x 10^{6}
30° to 300°C. . . . . 4.41 to 5.17 x 10^{6}
30° to 400°C. . . . . 4.54 to 5.08 x 10^{6}
30° to 450°C. . . . . 5.03 to 5.37 x 10^{6}
30° to 500°C. . . . . 5.71 to 6.21 x 10^{6}

The temperature of transformation from the gamma to alpha phase, as determined from expansion measurements, shall be not above minus 80°C.

STUPAKOFF CERAMIC
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Products for the World of Electronics

CERAMIC INSULATORS FOR ALL FREQUENCIES, VOLTAGES
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KOVAR—*The Ideal Alloy for Sealing to Glass* • GLASS TO METAL HERMETIC SEALS

Kovar is distributed by Stupakoff Ceramic and Manufacturing Company for Westinghouse Electric Corporation.

Seals made of Kovar and glass are covered by Westinghouse patents such as—
2,062,335 and 2,217,421

Alloys like the one presently known as Kovar are covered by patents such as 1,942,260.

Seals are also covered by Stupakoff Ceramic and Manufacturing Company patents such as—
2,318,435, 2,220,690 and 2,373,720

For the duration of the war and six months thereafter Westinghouse licensed the U. S. Government and Army and Navy in fields of radio and radiated electrical energy and by virtue of this license during the war, many were supplied Kovar for Army and Navy use.